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A Light at the End of the Tunnel

by Frank V. Botelho

The West Portal of the Lincoln Tunnel, which passes under the Hudson River and connects Weehawken, N.J., and Manhattan in New York City.
(Photo courtesy of the Port Authority of New York and New Jersey

As he paced the platform, waiting for the Washington express, he remembered that there were people who thought there would one day be a tunnel under the Hudson through which the trains of the Pennsylvania railway would run straight into New York. They were of the brotherhood of visionaries who likewise predicted the building of ships that would cross the Atlantic in five days, the invention of a flying machine, lighting by electricity, telephonic communication without wires, and other Arabian Night marvels.

- *Edith Wharton,* The Age of Innocence

Tunnel Vision

As we stand at the dawn of the 21st century, we can see the ingenious technological advancements that visionaries have brought to the world of transportation. A testament to this advancement is the existing infrastructure that includes some 400 highway-related tunnels of various lengths in 35 states and 1,055 kilometers (655 miles) of transit tunnels throughout the United States.

The bulk of tunnel construction occurred during certain periods of time. At the beginning of the 20th century, the New York and Boston transit systems were constructed. In the 1930s, tunnel ventilation technology was developed. And in the 1960s and 1970s, the construction of the Interstate Highway System was at its peak, and new transit systems were built in cities such as Atlanta, Baltimore, Dallas, San Francisco, and Washington.

In addition to the engineering expertise needed to design and build tunnels, today's visionaries also have to know how to properly manage and preserve them.

"We can't simply design and build tunnels and expect them to take care of themselves," said Vincent F. Schimmoller, deputy executive director of the Federal Highway Administration (FHWA). We must apply sound engineering and business principles to maintain our tunnels. Owners of tunnels have, in some instances, underestimated the cost and engineering complexity required to preserve their investment.

Although the nation's highway and transit tunnels have performed well and are safe, they are beginning to show their age. A recent report prepared by the Federal Transit Administration (FTA) rated the condition of 28 percent of transit underground structures as "substandard" or "poor." As many tunnel components are reaching the end of their service life, deferred or neglected maintenance can potentially exacerbate their condition. If a tunnel is not properly preserved through periodic maintenance and rapid repair of manageable problems, the tunnel owner will eventually have to choose from two very undesirable options: shut down the tunnel, accepting the resulting impact on the highway or transit system, or invest in very costly reconstruction also with potential system repercussions during the period of reconstruction.

To help ensure the proper preservation of the nation's tunnels, FHWA and FTA have joined forces to develop a state-of-the-art tunnel management system, a process that will extend the service life and reduce the operating expenses of tunnels throughout the country. FHWA and FTA recently hired Gannett Fleming Inc., a consulting engineering and construction management firm, to develop an extensive guide that will cover every step of the process. The tunnel management system guide is scheduled to be completed in 2002.

While some tunnel owners have already developed their own tunnel management systems, currently there are no national guidelines. Most guideline materials, handbooks, and procedural manuals for the inspection and maintenance of tunnels have been developed by a few proactive tunnel owners. This sporadic approach shows much variability in the depth and the breadth of tunnel management procedures. The new highway and transit tunnel management guide provides the best practices in a comprehensive system of tunnel management.

The guide will cover the following steps of the tunnel management system/process:

- Establish a database that includes an inventory of tunnel assets; historical files for all tunnel construction, maintenance, rehabilitation, and the cost of repairs; and records of inspections. Optional, generic (nonproprietary) software with instructions for completing each of these tasks and an explanation of record-keeping procedures will be provided.
- Select appropriate maintenance and rehabilitation techniques.
- Conduct analyses for the prioritization of repairs.
- Design management reports for future needs.
- Integrate tunnel management into asset management.

Inspectors check the ceiling tiles in Lehigh Tunnel No. 1 on the Pennsylvania Turnpike.
(Photo courtesy of the Pennsylvania Turnpike Commission)

"The tunnel management system will have complete and open distribution," said Anthony Caserta, senior tunnel engineer with FHWA. "It will be made available to all highway and transit agencies, owners, and operators. We think it will become an invaluable tool in maintaining and preserving our nation's tunnel assets."

Many Tunnels, ONE DOT

Both FHWA and FTA place a high priority on tunnel management. During the planning of their respective programs, officials in both agencies recognized that a tunnel is a tunnel regardless of what passes through it. This common understanding led to the consolidated ONE DOT effort to develop a tunnel management system for both highway and transit tunnels.

ONE DOT is a management strategy of the U.S. Department of Transportation (DOT) "that builds on the strength of mutual collaboration between the various agencies and functional 'communities of interest' when those cross-cutting efforts reduce duplication and save resources. Collaboration enables modes to solve common problems and serve customers more effectively, thereby achieving the vision, mission, and goals specified in DOT's Strategic Plan." (See "We Are ONE DOT!" in Public Roads, January/February 1999, pages 30-35.)

"By offering a systematic framework and the analytical tools to better manage America's highway and transit tunnels, the Tunnel Management System will help to improve safety and enhance mobility - two of our key transportation goals, " said Secretary of Transportation Norman Y. Mineta. "And by working together to develop the system, the Federal Highway Administration and the Federal Transit Administration have provided an ideal example of a ONE DOT approach that maximizes service and optimizes efficiency."

"This Tunnel Management System project is a classic example of the strength and technological advantage we can achieve by combining our efforts and pooling our resources. We are developing powerful tools and management systems that best address the issues faced by tunnel owners and operators," said Hiram Walker, FTA's acting deputy administrator.

"Using a ONE DOT approach, we will build upon this research with further assessments and development of future best tunnel management programs," said Edward L. Thomas, FTA's associate administrator for the Office of Research, Demonstration, and Innovation.

Big Picture

An effective tunnel management system is just one facet of transportation asset management that can be defined as a systematic process of maintaining, upgrading, and operating physical assets cost-effectively.

"Today's transportation environment is characterized by high user demand, stretched budgets, declining staff resources, and a transportation system that is showing the signs of age," said Madeleine Bloom, director of FHWA's Office of Asset Management. "Long used by the private sector to make investment, preservation, operation, and resource-allocation decisions, asset management is now slowly and surely transforming the way owners and operators of transportation infrastructure are prioritizing their many fiduciary obligations."

In the asset management process, all physical assets, such as tunnels, with all their individual components are routinely examined and analyzed. The first step is to collect fundamental data that include an inventory and to inspect the condition of all of the elements. The second step is to model the performance by predicting the future condition and life cycle of each asset. For example, in tunnel management, how much longer will the tunnel lining be considered reliable and structurally sound? In the third step, analysts use life-cycle cost analysis to evaluate various treatments and strategies. In the fourth step, decision-makers establish the program for maintenance activities and capital improvement projects. The fifth step is to implement the approved program. The sixth and last step is to monitor performance and feed the information back into the system and repeat the process on an annual basis.

Proactive Tunnel Management

Some tunnel owners and operators, recognizing that a proactive and systematic approach to tunnel management will directly improve the efficiency and effectiveness of their entire highway or transit system, developed their own tunnel management systems.

For example, the New York City Transit Authority used a tunnel management system to complete the recent rehabilitation of the 42nd Street/Grand Central Subway Station. This effort was designed to preserve and improve one of the oldest and most heavily used subway stations in the country. The $74 million dollar contract included tile replacement, lighting, electrical improvements, and other rehabilitative measures.

Another example is an asset management contract to preserve all components of the National Highway System (NHS) - including pavements, bridges, tunnels, and hardware - in the nation's capital. The contract cost is $70 million over five years. About $25 million (36 percent of the total budget) has been earmarked for tunnel preservation.

A third example is the system used by the Port Authority of New York and New Jersey, which manages the Holland and Lincoln tunnels, along with bridges, terminals, airports, shipping, and waterfront development promoting economic growth in the bistate region. Its tunnel management program has evolved from necessity over the last three decades in response to greater operational complexity.

"Although we don't formally call it an asset management program, we utilize all of the same basic steps in all of our maintenance and capital improvement projects, " said Steve Fiorelli, manager of tunnel projects for the Port Authority. "Having a systematic process ultimately allows us to provide better service to our customers in the form of fewer lane closures and delays."

The technical experts who developed the tunnel management system are: (from left) Anthony Caserta, FHWA, senior tunnel engineer; George Romack, FHWA, senior bridge management engineer; Mary Louise Anderson, FTA, general engineer; Sam Nassif, FTA, program engineer; and Frank Botelho, FHWA, team leader of the Management Systems and

The FHWA/FTA Tunnel Management System will help tunnel owners and operators all across the country identify potential problems within their tunnels and will provide guidelines for proper maintenance to extend the life of a tunnel and/or to avoid more costly problems later. With an effective management system, operators can minimize damage, disruption of service, and traffic delays caused by typical tunnel problems such as those caused by groundwater and inadequate ventilation.

The number one problem affecting all tunnels is damage caused by groundwater. The Transit Cooperative Research Program report (TCRP Synthesis 23, "Inspection Policy and Procedures for Rail Transit Tunnels and Underground Structures") says, "Groundwater intrusion is responsible for more problems affecting a tunnel's concrete liners and steel-reinforced concrete than all other tunnel structural problems combined." Concrete spalling and delamination, in turn, trigger a new set of complications that may make the tunnel unusable. Uncontrolled water can potentially cause electrical shorts and other dangerous situations. Therefore, adequate drainage and clearance of water from the tunnel and traveled way is a major maintenance consideration.

Maintaining the ventilation system in a tunnel is the second most critical maintenance activity. It can be as straightforward as greasing bearings and replacing belts. But if not properly maintained, the huge motor-driven fans can rust and malfunction, requiring costly replacement. And more importantly, improperly maintained fans can create a significant health hazard for motorists who use the tunnel and can greatly increase the potential for fire.

These are only two of many potential problems in tunnels. The list of activities and expenditures required to keep a tunnel in good, safe working condition is

long. Developing a systematic framework and practical tools to better manage the nation's highway and transit tunnels is the focus of FHWA and FTA's ONE DOT tunnel management efforts.

Tunnels for the Future

Even the visionaries in Edith Wharton's The Age of Innocence could not have envisioned the engineering complexity and huge funding requirements needed to preserve and operate today's transportation systems. Likewise, it is difficult to envision what transportation will look like a century from now. But with incremental steps like the national Tunnel Management System, the tunnels in Wharton's crossing of the Hudson River will still be there to tell the tale.

Frank V. Botelho is the team leader for the Management Systems and Monitoring Team in FHWA's Office of Asset Management. He is a civil engineer and has been with FHWA for 35 years. He has extensive experience in management systems and asset management.

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